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(54) **ELECTRONIC FUEL CONVERTIBILITY SELECTION**

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(52) **U.S. Cl.** .... **431/18**; 431/80; 431/90; 126/39 BA

(58) **Field of Search** .... 431/12, 18, 90, 431/89, 80, 62, 78, 79; 137/113; 236/26 A; 126/39 BA, 39 R, 39 N

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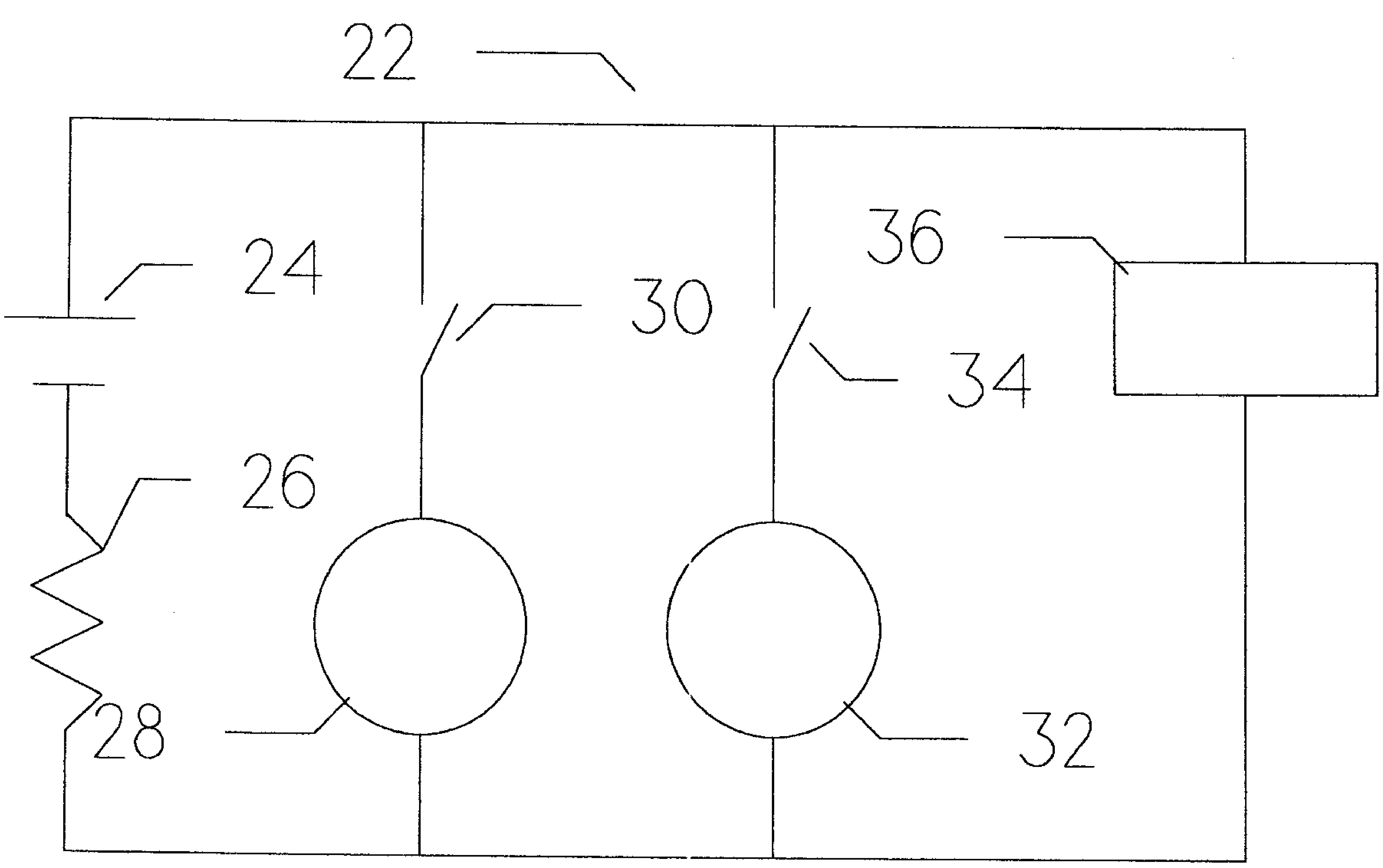
Primary Examiner—James C. Yeung

(57) **ABSTRACT**

An apparatus for and method for providing easy and rapid conversion from a first fuel to a second fuel in a gas appliance. The gas appliance has a variable fuel valve controlled by a microprocessor. A table stored in non-volatile memory has an entry for each of the fuels to be burned in the gas appliance. The table entries are empirically determined at the time of manufacture.

26 Claims, 5 Drawing Sheets



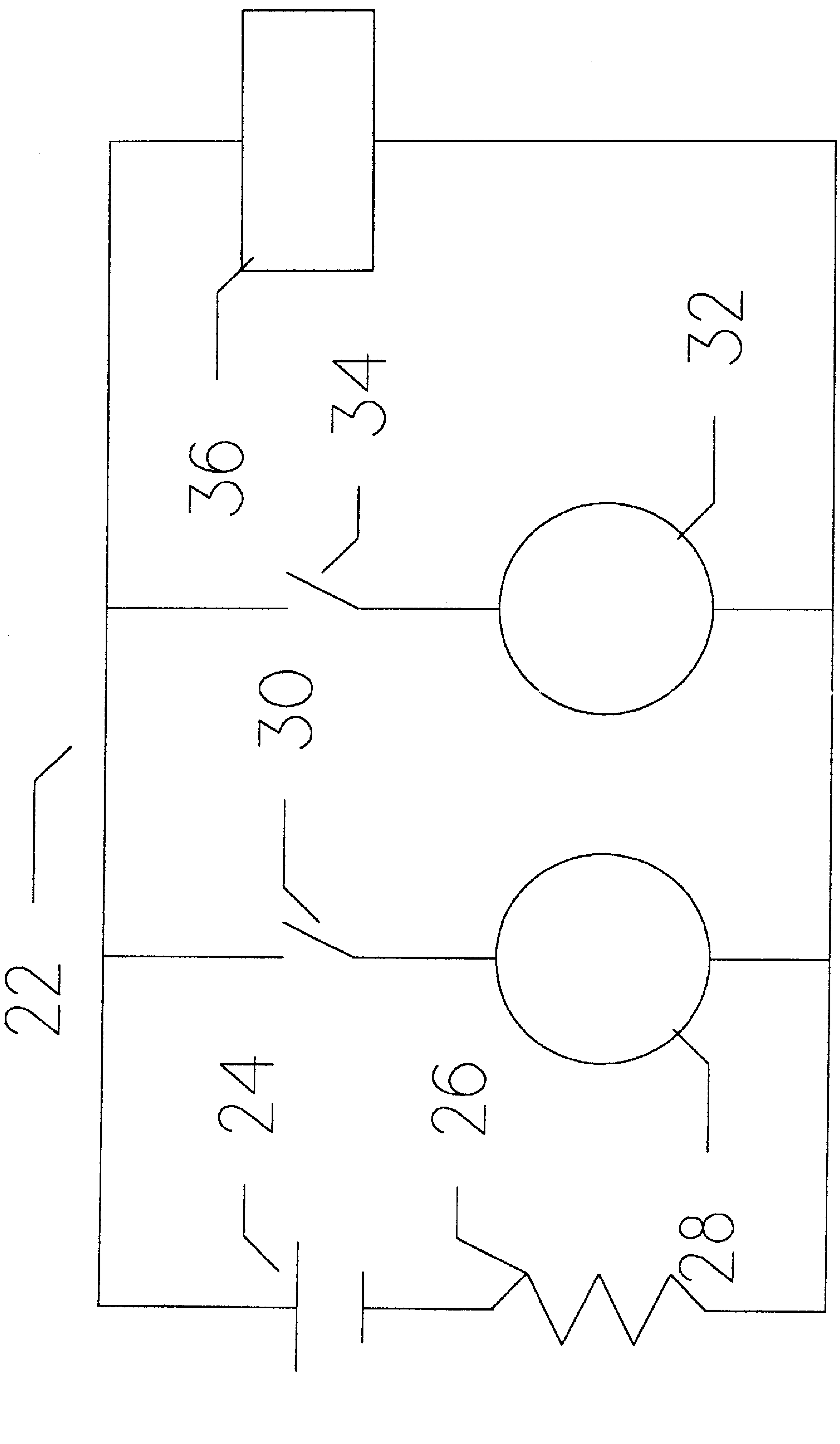


FIG. 1

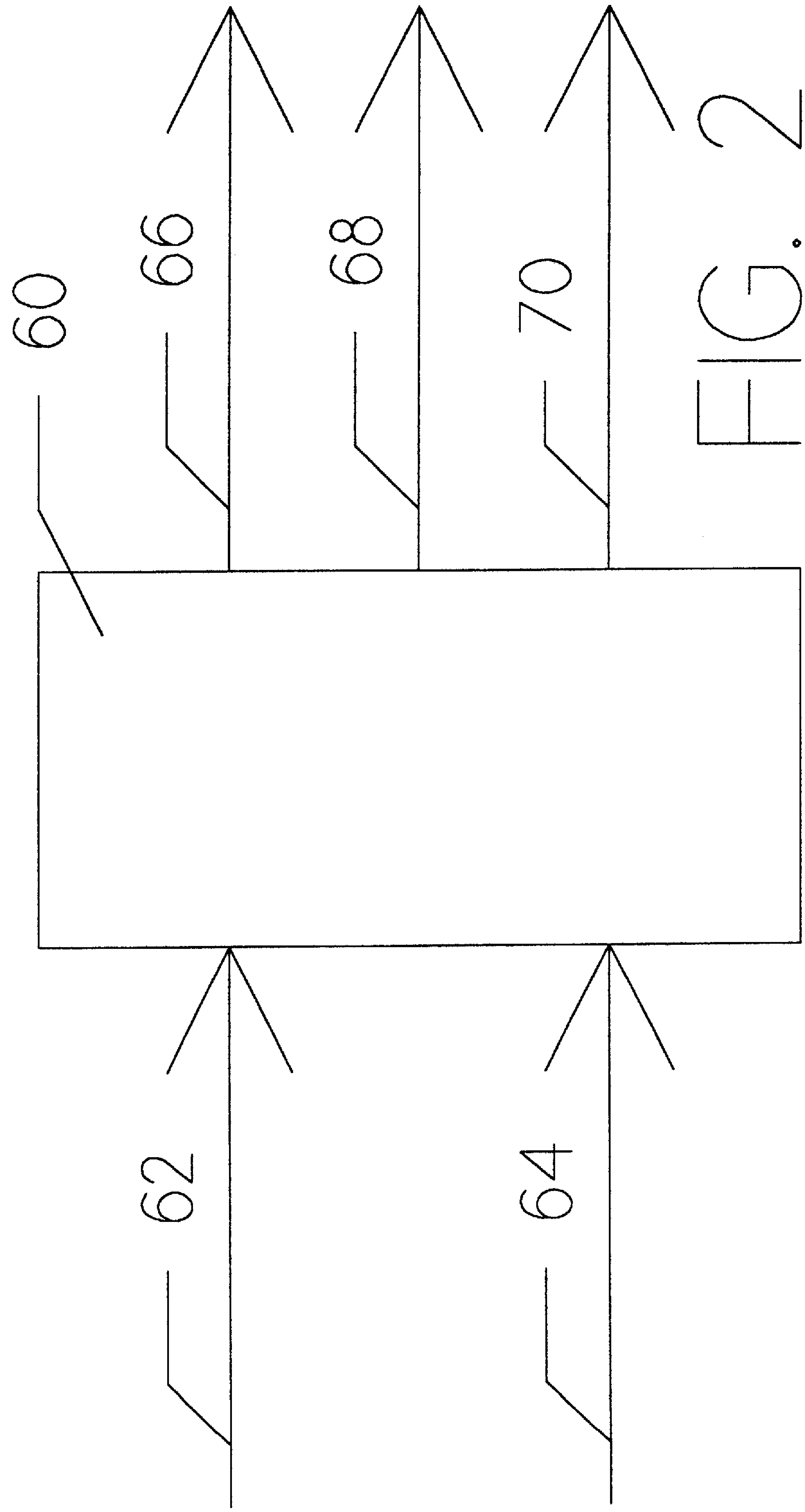


FIG. 2

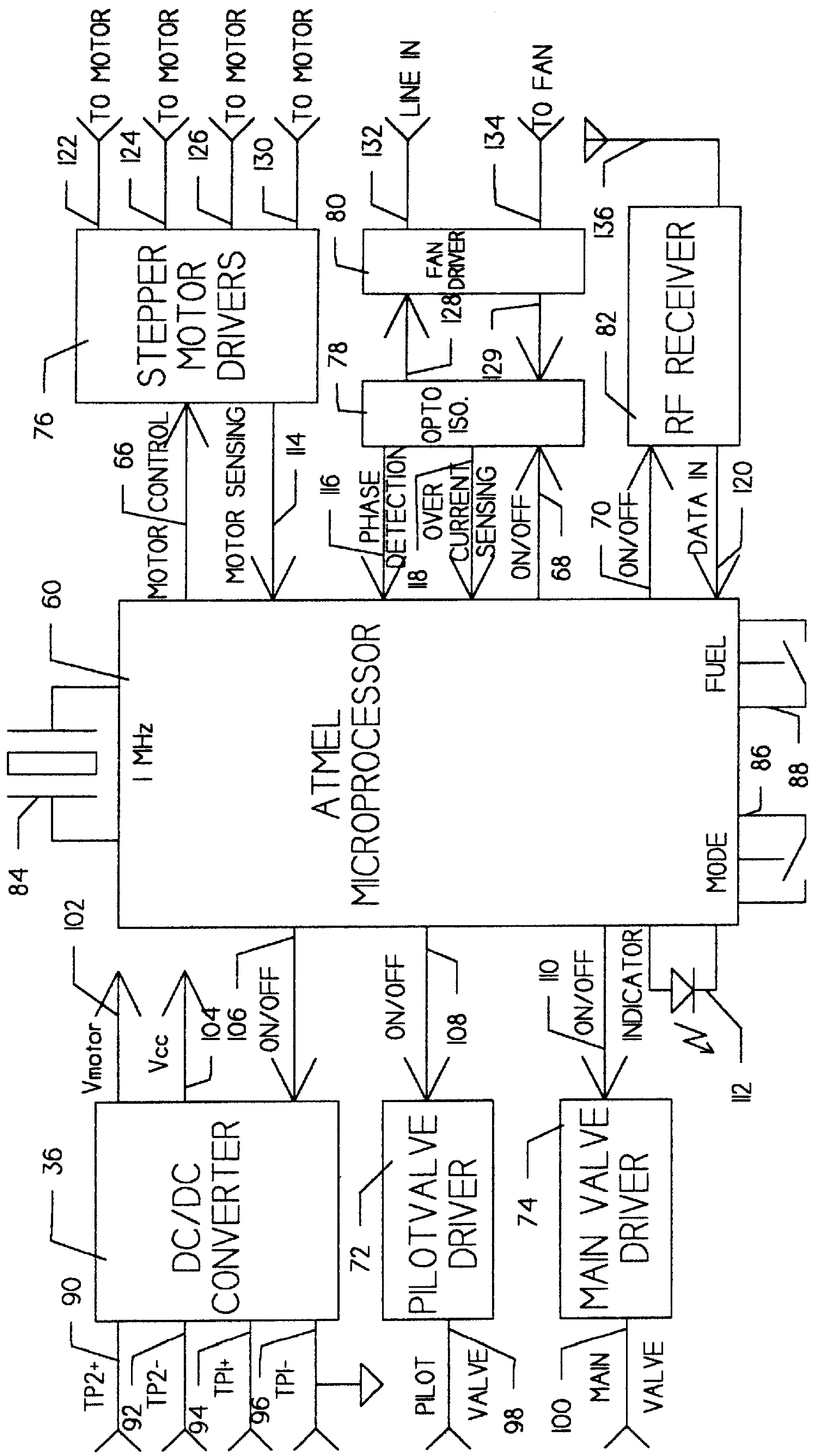

TO MOTOR
TO MOTOR
TO MOTOR
TO MOTOR
122
124
126
130
LINE IN
132
TO FAN
134
80
FAN DRIVER
128
129
136
STEPPER MOTOR DRIVERS
76
78
OPTO ISO.
82
RF RECEIVER
66
MOTOR CONTROL
MOTOR SENSING
114
116
PHASE DETECTION
118
OVER CURRENT SENSING
ON/OFF
68
70
ON/OFF
DATA IN
120
60
1 MHz
ATMEL MICROPROCESSOR
FUEL
86
88
MODE
84
102
Vmotor
Vcc
104
106
ON/OFF
ON/OFF
108
110
ON/OFF
INDICATOR
112
36
DC/DC CONVERTER
90
72
PILOTVALVE DRIVER
74
MAIN VALVE DRIVER
TP2+
92
TP2-
94
TP1+
96
TP1-
PILOT
VALVE
98
100
MAIN
VALVE

FIG. 3

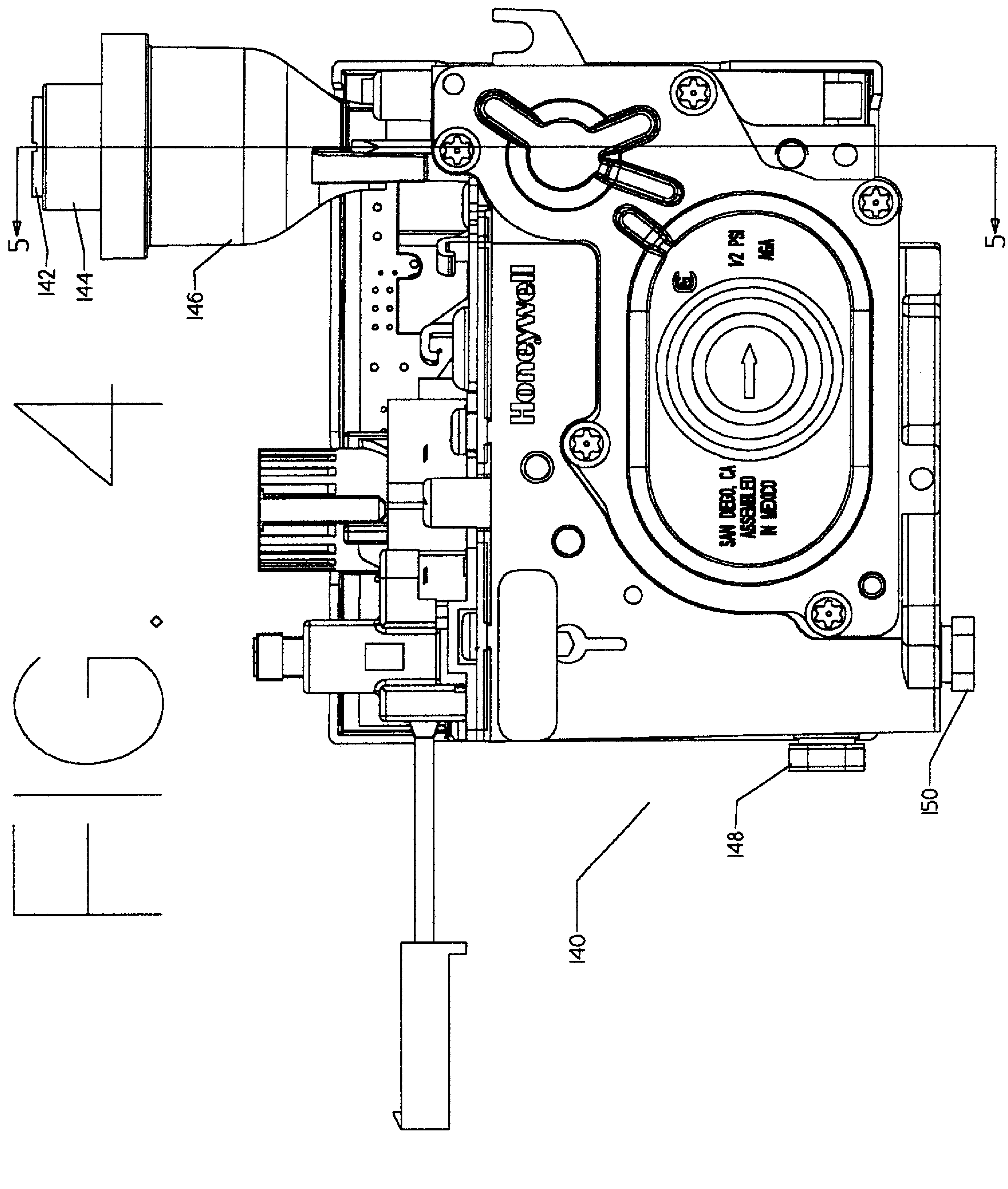
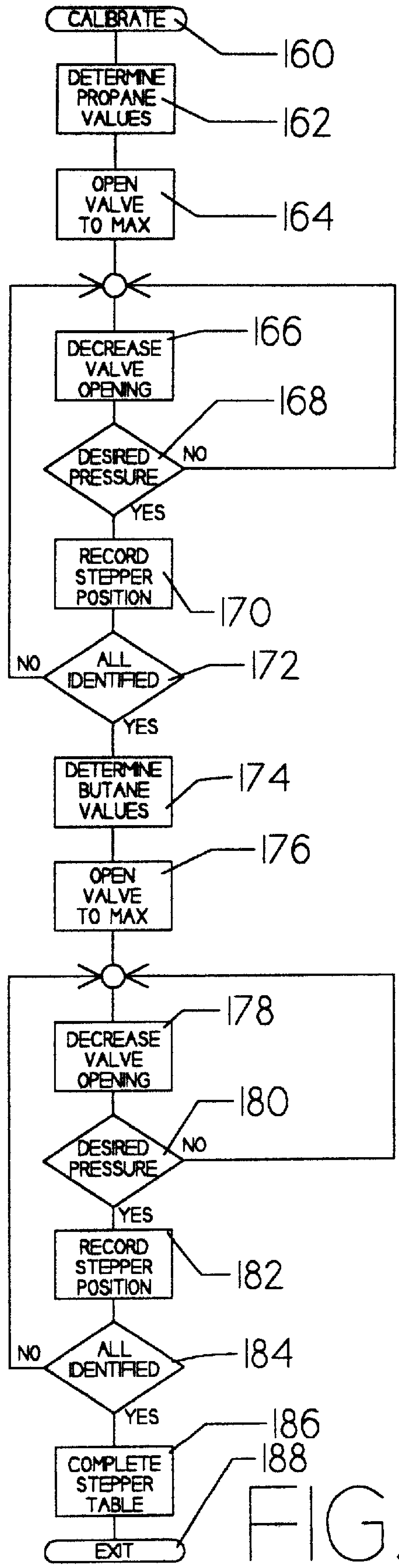

5
5
142
144
146
140
148
150
Honeywell
1/2 PSI
AGA
SAN DIEGO, CA
ASSEMBLED
IN MEXICO

FIG. 4



CALIBRATE
160
DETERMINE PROPANE VALUES
162
OPEN VALVE TO MAX
164
DECREASE VALVE OPENING
166
DESIRED PRESSURE
168
NO
YES
RECORD STEPPER POSITION
170
ALL IDENTIFIED
172
NO
YES
DETERMINE BUTANE VALUES
174
OPEN VALVE TO MAX
176
DECREASE VALVE OPENING
178
DESIRED PRESSURE
180
NO
YES
RECORD STEPPER POSITION
182
ALL IDENTIFIED
184
NO
YES
COMPLETE STEPPER TABLE
186
EXIT
188

FIG. 5

ELECTRONIC FUEL CONVERTIBILITY SELECTION

CROSS REFERENCE TO CO-PENDING APPLICATIONS

U.S. patent application Ser. No. 09/447,611, filed Nov. 23, 1999, and entitled, "LOW INPUT VOLTAGE, LOW COST, MICRO-POWER DC-DC CONVERTER"; U.S. patent application Ser. No. 09/447,999, filed Nov. 23, 1999, and entitled, "STEPPER MOTOR DRIVING A LINEAR ACTUATOR OPERATING A PRESSURE CONTROL REGULATOR"; U.S. patent application Ser. No. 09/448,102, filed Nov. 23, 1999, and entitled, "LOW INPUT VOLTAGE, HIGH EFFICIENCY, DUAL OUTPUT DC TO DC CONVERTER"; and U.S. patent application Ser. No. 09/448,000, filed Nov. 23, 1999, and entitled, "ELECTRONIC DETECTING OF FLAME LOSS BY SENSING POWER OUTPUT FROM THERMOPILE" are commonly assigned co-pending applications incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to systems for control of a gas appliance incorporating a flame and more particularly relates to fuel control valve systems.

2. Description of the Prior Art

It is known in the art to employ various appliances for household and industrial applications which utilize a fuel such as natural gas (i.e., methane), propane, or similar gaseous hydrocarbons. Typically, such appliances have the primary heat supplied by a main burner with a substantial pressurized gas input regulated via a main valve. Ordinarily, the main burner consumes so much fuel and generates so much heat that the main burner is ignited only as necessary. At other times (e.g., the appliance is not used, etc.), the main valve is closed extinguishing the main burner flame.

A customary approach to reigniting the main burner whenever needed is through the use of a pilot light. The pilot light is a second, much smaller burner, having a small pressurized gas input regulated via a pilot valve. In most installations, the pilot light is intended to burn perpetually. Thus, turning the main valve on provides fuel to the main burner which is quickly ignited by the pilot light flame. Turning the main valve off, extinguishes the main burner, which can readily be reignited by the presence of the pilot light.

These fuels, being toxic and highly flammable, are particularly dangerous in a gaseous state if released into the ambient. Therefore, it is customary to provide certain safety features for ensuring that the pilot valve and main valve are never open when a flame is not present preventing release of the fuel into the atmosphere. A standard approach uses a thermogenerative electrical device (e.g., thermocouple, thermopile, etc.) in close proximity to the properly operating flame. Whenever the corresponding flame is present, the thermocouple generates a current. A solenoid operated portion of the pilot valve and the main valve require the presence of a current from the thermocouple to maintain the corresponding valve in the open position. Therefore, if no flame is present and the thermocouple(s) is cold and not generating current, neither the pilot valve nor the main valve will release any fuel.

In practice, the pilot light is ignited infrequently such as at installation, loss of fuel supply, etc. Ignition is accomplished by manually overriding the safety feature and holding the pilot valve open while the pilot light is lit using a match or piezo igniter. The manual override is held until the heat from the pilot flame is sufficient to cause the thermocouple to generate enough current to hold the safety solenoid. The pilot valve remains open as long as the thermocouple continues to generate sufficient current to actuate the pilot valve solenoid.

The safety thermocouple(s) can be replaced with a thermopile(s) for generation of additional electrical current. This additional current may be desired for operating various indicators or for powering interfaces to equipment external to the appliance. Normally, this requires conversion of the electrical energy produced by the thermopile to a voltage useful to these additional loads. Though not suitable for this application, U.S. Pat. No. 5,822,200, issued to Stasz; U.S. Pat. No. 5,804,950, issued to Hwang et al.; U.S. Pat. No. 5,381,298, issued to Shaw et al.; U.S. Pat. No. 4,014,165, issued to Barton; and U.S. Pat. No. 3,992,585, issued to Turner et al. all discuss some form of voltage conversion.

Upon loss of flame (e.g., from loss of fuel pressure), the thermocouple(s) ceases generating electrical current and the pilot valve and main valve are closed, of course, in keeping with normal safety requirements. Yet this function involves only a binary result (i.e., valve completely on or valve completely off). Though it is common within vehicles, such as automobiles, to provide variable fuel valve control as discussed in U.S. Pat. No. 5,546,908, issued to Stokes, and U.S. Pat. No. 5,311,849, issued to Lambert et al., it is normal to provide static gas appliances with a simple on or off, linearly actuated valve having the desired safety features.

Yet, there are occasions when it is desirable to adjust the valve outlet pressure regulation point of the main burner supply valve of a standard gas appliance. These include changes in mode (i.e., changes in the desired intensity of the flame) and changes in the fuel type (e.g., a change from propane to methane). U.S. Pat. No. 5,234,196, issued to Harris; U.S. Pat. No. 4,816,987, issued to Brooks et al.; U.S. Pat. No. 5,873,351, issued to Vars et al.; and U.S. Pat. No. 5,150,685, issued to Porter et al., suggest approaches to variable valve positioning of a gas appliance. However, the introduction of an entirely new valve design is likely to introduce severe regulatory difficulties. The present safety valve approach has been used for such a long time with satisfactory results. Proof of safe operation of a new approach to valve design would require substantial costly end user testing.

SUMMARY OF THE INVENTION

The present invention overcomes the disadvantages of the prior art by providing a main burner valve for a gas appliance which offers the user the opportunity to quickly and easily change the main valve outlet pressure regulation point to accommodate changes in fuel type. The main burner valve of the present invention utilizes a standard, linearly actuated valve design having proven safety features, but which also offers precisely controllable differing outlet pressure. Linear actuation is important, because it offers the normal safety features associated with the industry standard of full off upon flame out. However, because the valve of the present invention may be positioned along the entire length of its travel from full open to full closed, the valve is totally adjustable permitting changes in mode, fuel input, and other outlet pressure related features.

In accordance with the preferred mode of the present invention, a thermopile is thermally coupled to the pilot flame. As current is generated by the thermopile, it is converted via a DC-to-DC converter to a regulated output and an unregulated output. The regulated output powers a microprocessor and other electronic circuitry which control operation of the main fuel valve in response to sensed conditions, operator inputs, and certain stored data. The unregulated output powers various mechanical components including a stepper motor.

The stepper motor is mechanically coupled to a linear actuator which precisely positions the main fuel valve. Because the main fuel valve is linearly actuated, it operates in known fashion with respect to the industry proven flame out safety features. Yet, the stepper motor, under direct control of the microprocessor, positions the linear actuator for precise valve positioning and therefore, fuel input modulation to the burner.

The use of a stepper motor means that any selected valve position is held statically by the internal rachet action of the stepper motor without quiescent consumption of any electrical energy. That makes the electrical duty cycle of the stepper motor/valve positioning system extremely low. This is a very important feature which permits the system to operate under the power of the thermopile without any necessary external electrical power source. In fact, the stepper motor duty cycle is sufficiently low, that the power supply can charge a capacitor slowly over time such that when needed, that capacitor can power the stepper motor to change the position of the linear actuator and hence the main fuel valve outlet pressure regulation point.

In accordance with the present invention, the gas appliance is calibrated during the manufacturing process. The stepper motor values and hence the valve positioning data corresponding to the desired valve settings are determined empirically for the various fuel types. This information is stored within non-volatile memory of the microprocessor. Thus, a table of stepper motor commands are available to the microprocessor for rapid changes of fuel type.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects of the present invention and many of the attendant advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, in which like reference numerals designate like parts throughout the figures thereof and wherein:

FIG. **1** is a simplified electrical schematic diagram of the present invention;

FIG. **2** is a simplified block diagram of the microprocessor of the present invention;

FIG. **3** is a detailed electrical block diagram;

FIG. **4** is a plan view of the valve assembly; and

FIG. **5** is a flow diagram showing calibration of the valve assembly.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** is a very basic electrical diagram **22** of the power circuitry of the present invention. Thermopile **24** is structured in accordance with the prior art. Resistor **26** represents the internal resistance of thermopile **24**.

Pilot valve **28** has a solenoid (not separately shown) which holds the pilot valve closed whenever sufficient current flows through the circuit. Similarly, the internal solenoid (also not separately shown) main valve **32** holds the main valve closed whenever sufficient current flows through the associated circuit.

DC-to-DC conversion facility **36** converts the relatively low voltage output of thermopile **24** to a sufficiently large voltage to power the electronic circuitry, including the microprocessor. In accordance with the preferred mode of the present invention, DC-to-DC conversion facility **36** consists of two DC-to-DC converters. The first converter operates at the extremely low thermopile output voltages experienced during combustion chamber warm up to generate a higher voltage to start the higer efficiency, second DC-to-DC converter. The other DC-to-DC converter, once started, can keep converting at much lower input voltage and generate much more power from the limited thermopile output for the system during normal operation. A more detailed description of the second device is available in the above identified and incorporated, commonly assigned, co-pending U.S. Patent Applications.

FIG. **2** is a simplified diagram showing the basic inputs and outputs of microprocessor **60**. In the preferred mode, microprocessor **60** is an 8-bit AVR model AT90LS8535 microprocessor available from ATMEL. It is a high performance, low power, restricted instruction set (i.e., RISC) microprocessor. In the preferred mode, microprocessor **60** is clocked at one megahertz to save power, even though the selected device may be clocked at up to four megahertz.

The two primary inputs to microprocessor **60** are the thermopile output voltage received via input **62** and the manual mode change information received via input **64**. The thermopile output voltage is input once per second. The mode change information, on the other hand, is received a periodically in response to manual action by the user.

Output **66** controls operation of the stepper motor. As is explained in more detail below, this affects management of the main fuel valve orifice size. Output **68** is the on/off control for the external circulation fan. Output **70** controls the radio frequency receiver through which an operator can communicate via a remote control device.

FIG. **3** is a detailed block diagram of the inputs and outputs of microprocessor **60**. One megahertz crystal **84** clocks microprocessor **60**. The output of crystal **84** is also divided down to provide an interrupt to microprocessor **60** once per second. This interval is utilized for sampling of the thermopile output voltage Indicator **112** permits early notification of flame on to the user.

Manual mode switch **86** permits an operator to select local mode or remote mode. Similarly, manual switch **88** is used to select the input fuel type, so that the main valve outlet pressure regulation point can be switched between propane and methane. Each of these alternative switch positions cause microprocessor **60** to consult a particular corresponding entry within the valve positioning table stored in the non-volatile memory of microprocessor **60**. These entries provide the necessary information for microprocessor **60** to direct the stepper motor to set the main burner valve outlet pressure to the proper value. The method for determining the valve positioning table entries is described in detail below.

DC-to-DC converter **36** can receiver inputs from up to two thermopiles. Inputs **94** and **96** provide the positive and negative inputs from the first thermopile, whereas inputs **90** and **92** provide the positive and negative inputs from the second thermopile, respectively. Output **102** is the unregulated output of DC-to-DC converter **36**. This output has a voltage varying between about 6 volts and 10 volts. The unregulated output powers the mechanical components, including the stepper motor. Line **104** is a 3 volt regulated output. It powers microprocessor **60** and the most critical electronic components. Line **106** permits microprocessor to power DC-to-DC converter **36** up and down. This is consistent with the voltage sampling and analysis by microprocessor **60** which predicts flame out conditions.

Line **72** enables and disables pilot valve driver **72** coupled to the pilot valve via line **98**. Similarly, line **110** controls main valve driver **74** coupled to the main valve via line **100**. This is important because microprocessor **60** can predict flame out conditions and shut down the pilot and main valves long before the output of the thermopile is insufficient to hold the valves open. A more detailed description of this significant feature may be found in the above referenced, co-pending, commonly assigned, and incorporated U.S. Patent Applications.

Stepper motor drivers **76** are semiconductor switches which permit the output of discrete signals from microprocessor **60** to control the relatively heavy current required to drive the stepper motor. In that way, line **66** controls the stepper motor positioning in accordance with the direction of the microprocessor firmware. Line **114** permits sensing of the stepper motor status. Lines **122**, **124**, **126**, and **130** provide the actual stepper motor current.

In the preferred mode of practicing the present invention, the gas appliance is a fireplace. The thermopile output is not sufficient to power the desired fan. However, the system can control operation of the fan. Therefore, line **132** provides the external power which is controlled **15** by fan driver **80**. Lines **128** and **129** couple to optical isolation device **78** for coupling via lines **68**, **116**, and **118** to microprocessor **60**. Line **134** actually powers the fan.

The fireplace of the preferred mode also has radio frequency remote control. A battery operated transmitter communicates with rf receiver **82** via antenna **136**. Lines **70** and **120** provide the interface to microprocessor **60**. Rf receiver **82** is powered by the 3 volt regulated output of DC-to-DC converter **36** found on line **104**.

FIG. **4** is a plan view of the valve assembly **140** of the preferred mode of the present invention. Fuel inlet **150** has standard fittings. Similarly, gas outlet **148** includes a standard coupling. Regulator cap **142** fits within housing cap **144** as shown (a better view is found in the section of FIG. **5**). Motor housing **146** contains the linear actuator and stepper motor (neither shown in this view).

FIG. **5** is a flow diagram showing the manner in which the entries are empirically determined for the valve positioning table. Entry is via element **160**. The propane valve positioning values are determined first. The stepper motor opens the valve to its maximum position at element **164**.

At element **166**, the stepper motor decrements the outlet pressure of the valve. The outlet pressure is determined at element **168**. If the pressure is not as desired, control is returned to element **166** for a further decrement of the outlet pressure. When the valve pressure has been decremented to the desired point, control is given by element **168** to element **170**. The stepper motor positioning command is stored in the valve positioning table by element **170**. Element **72** determines whether there are other propane entries to be determined. If yes, control is given to element **166** to continue the process.

After element **172** finds that all of the propane entries have been made in the valve positioning table, control is given to element **174** to initialize for determine the methane (or natural gas) values. The process is essentially repeated for methane. Element **176** opens the valve to the maximum outlet pressure. Decrementation of the valve outlet pressure is accomplished by element **178**. Element **180** determines if the desired value has been reached. If no, the process continues at element **178**. If yes, element **182** records the stepper motor value. Element **184** ascertains whether all of the methane values have been determined. If not, control is given to element **178**. If yes, element **186** completes the valve positioning table, and exit is made via element **188**.

Having thus described the preferred embodiments of the present invention, those of skill in the art will be readily able to adapt the teachings found herein to yet other embodiments within the scope of the claims hereto attached.

We claim:

1. In a gas appliance having a flame produced by a main burner configured to burn at least two different types of fuels wherein said flame of said main burner is controlled by a main valve and having a second flame produced by a second burner coupled to a one of said two different types of fuels, the improvement comprising:

a. a current generation device; and

b. a switch powered by said current generation device which changes said main valve from a first fuel source to a second fuel source by electrically modifying said main valve from a first predetermined outlet pressure to a second predetermined outlet pressure.

2. The improvement according to claim **1** further comprising an electronic circuit powered by said current generation device for controlling the position of said main valve.

3. The improvement according to claim **2** wherein said electronic circuit further comprises a microprocessor powered by said current generation device.

4. The improvement according to claim **3** wherein said further microprocessor further comprises non-volatile memory.

5. The improvement according to claim **4** wherein said non-volatile memory stores a first quantity corresponding to said first predetermined outlet pressure and a second quantity corresponding to said second predetermined outlet pressure.

6. The improvement according to claim **5**, wherein the first and second quantities stored by the non-volatile memory relate to valve positioning.

7. The improvement according to claim **6**, wherein the first and second quantities stored by the non-volatile memory are stepper motor values.

8. An apparatus comprising:

a. a flame;

b. a gas inlet;

c. a gas outlet;

d. a valve having a variable outlet pressure interposed between said gas inlet and said gas outlet; and

e. an electrical device powered by said flame responsively coupled to said valve which controllably varies said outlet pressure from a first predetermined value to a second predetermined value.

9. An apparatus according to claim **8** wherein said electrical device further comprises a microprocessor.

10. An apparatus according to claim **9** wherein said microprocessor further comprises a non-volatile memory.

11. An apparatus according to claim **10** wherein said non-volatile memory contains a first quantity corresponding to said first predetermined value and a second quantity corresponding to said second predetermined value.

12. An apparatus according to claim **11** wherein said first quantity corresponds to propane and said second quantity corresponds to methane.

13. The improvement according to claim **11** including an actuator coupled to the valve for positioning the valve, wherein the first and second quantities stored by the non-volatile memory relate to positioning the actuator.

14. The improvement according to claim **13**, including a stepper motor for positioning the actuator, wherein the first and second quantities stored by the non-volatile memory are stepper motor values.

15. A method of facilitating conversion of fuel type within a gas appliance having a valve with an adjustable outlet pressure comprising:

a. initializing calibration of said valve for a first fuel type;

b. changing said adjustable outlet pressure;

c. determining if outlet pressure of said valve is a desired value;

d. if said determining step determines no, repeating steps b and c; and

e. if said determining step determines yes, storing a quantity corresponding to said outlet pressure.

16. A method according to claim **15** further comprising:

a. repeating steps b through e for each of a plurality of desired values.

17. A method according to claim **16** further comprising:

a. reinitializing calibration of said valve for a second fuel type and repeating steps b through e.

18. A method according to claim **17** wherein said first fuel type is methane.

19. A method according to claim **18** wherein said second fuel type is propane.

20. An apparatus comprising:

a. means for generating a current from a flame;

b. means for supplying a first gas;

c. means responsively coupled to said supplying means for controlling flow of said first gas; and

d. means responsively coupled to said controlling means and powered by said generating means for electrically changing said flow.

21. An apparatus according to claim **20** further comprising:

a. means responsively coupled to said controlling means for supplying a second gas; and

b. means responsively coupled to said electrically changing means for converting from said first gas to said second gas.

22. An apparatus according to claim **21** wherein said changing means further comprises a microprocessor.

23. An apparatus according to claim **22** wherein said converting means further comprises a non-volatile memory.

24. An apparatus according to claim **23** further comprising:

a. a first quantity corresponding to said first gas stored within said non-volatile memory; and

b. a second quantity corresponding to said second gas stored within said non-volatile memory.

25. The improvement according to claim **24**, wherein the flow control means includes a valve and an actuator coupled to the valve for positioning the valve, wherein the first and second quantities stored by the non-volatile memory relate to valve positioning.

26. The improvement according to claim **25**, wherein the flow control means includes a stepper motor in operating relationship to the actuator, and wherein the first and second quantities stored by the non-volatile memory are stepper motor values.

* * * * *